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1. Your reference — HL73026 MJA

2. Patent application number *(The Patent Office will fill in this part)* — 16 AUG 1999 — **9919333.6**

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

FLYING NULL LIMITED

Harston Mill
Harston
Cambridge
CB2 5NH

Patents ADP number *(if you know it)* — 7070519001

If the applicant is a corporate body, give the country/state of its incorporation — England

4. Title of the invention

INFORMATION BEARING LABEL CODES

5. Full name of your agent *(if you have one)* — Haseltine Lake & Co.

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Imperial House
15–19 Kingsway
London WC2B 6UD

Patents ADP number *(if you know it)* — 34001

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Country	Priority application number *(if you know it)*	Date of filing *(day/month/year)*

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Number of earlier application	Date of filing *(day/month/year)*

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Date 16 August 1999

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Mike Abrams [0171] 420 0500

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1 INFORMATION BEARING LABEL CODES

1.1 Introduction

In certain types of human and machine-readable information-bearing label, a set of elements is used to represent the information contained in the label. This representation may be by varying the characteristics of the elements comprising the label, and also by the position in which the label elements are placed. Reading apparatus is used which senses the characteristics and placement of the elements in order to decode the information contained within the label. The elements in the label are sequentially scanned, to discover the presence of the constituent elements and to measure their characteristics and position.

This application details label coding methods by which information can be represented on such a label. In one embodiment the label is comprised of a plurality of magnetically active elements supported on a substrate, the magnetically active elements being capable of anisotropy. Information is coded by controlling the position and shape of the elements.

In another embodiment the label is comprised of a plurality of magnetically active elements supported on a substrate, the magnetically active elements being capable of anisotropy. Information is coded by controlling the angle of orientation of the easy axis and shape of the elements.

Another embodiment the label is comprised of a plurality of optically readable elements supported on a substrate. Information is coded by controlling the position and shape of the elements according to the invention described.

1.2 Description of the Invention

According to one aspect of the present invention a coding scheme is defined where information is encoded into the gaps between elements. Fig 1 shows an example of a linear label where the gaps are measured as the linear distance between the centres of the elements along the length of the label. In this instance the properties of each element are the same.

Fig 1: Linear label

Fig 1 shows a case with the gaps embodied as differences in the linear position of the centre of elements. Another embodiment for the codes is for the gaps to be embodied as angular differences in the centrelines of adjacent elements or angular differences in any directional physical property of the element.

Variation of the material properties is used to encode additional information. Properties that could be used include geometric and also physical properties of the

material elements. Fig 2 shows one instance where the properties of the elements are varied, in this example the height of the label. One or more such property may be simultaneously used to increase the total information content of the label.

Fig2: Linear label with coded element properties

In this coding scheme, the gaps between the centre points of adjacent elements can be one of a number of distinct possible sizes. The end elements of the label would typically be at a fixed distance between their centre points so as to ensure that the label is a constant length irrespective of the information coded into the label.

In a typical scheme, the minimum separation between elements would be determined by the capability of the reading method. For example where the elements are implemented as magnetically active elements which can be individually interrogated by an applied field, the minimum separation may be 1.5 millimetres. The gaps are typically any integer multiple of a fixed distance, chosen with regard to the capability of the reading method. The gap increment may typically be 0.75mm. Since the end elements are fixed in position, for a given number of elements in the label, the sum of all the gaps must be a constant distance, which when divided by the gap increment will be an integer, the maximum gap size. Each gap can be characterised and represented as the multiple of the gap increment. This multiple g is an integer ranging from 0 to the maximum gap size. These multiples are denoted g1,g2,g3...gG where there are G gaps, G is one less than the total number of elements in the label.

Each sequence of integers g1,g2,g3...gG whose sum is the maximum gap size therefore represents a unique code in the code space which is characterised by the number of gaps G, and the maximum gap size M. For instance for the label shown in Fig 1 which has 10 elements and a maximum gap size of 18, the gap sequence for the label code shown is 3,2,2,1,7,0,0,2,1 and there are 1562275 unique codes that can be represented in this code space.

By varying the number of elements for a given fixed label length, the number of codes that can be represented is increased.

A method of comparing codes is defined so that if we had 2 codes {a} and {b} for which the gap sequences were a1,a2,a3,...,aG and b1,b2,b3, ,bG then {a} is "greater" than {b} if a1 is greater than b1, or if a1 is the same as b1 then by comparing a2 and b2 and so on up to aN and bN.

A typical enumeration method is to tabulate the gap sequences in order of magnitude for example by ensuring that the first sequence in the table is "greater" than the second sequence, the second sequence is "greater" than the third sequence and so on. The enumerated code is then the position of the matching gap sequence in the table.

According to another aspect of the present invention there is a Bi-directional coding scheme by which same the label code is determined irrespective of whether the label, for example that shown in Fig 1, is read from left to right, or right to left.

The sequences are "equal" if all the corresponding gaps in {a} and {b} are the same.

The Bi-directional codes are generated by permuting unique gap sequences for example the gap sequence 3,2,2,1,7,0,0,2,1 above. The reverse of the gap sequence is formed to produce 1,2,0,0,7,1,2,2,3 in this case. The sequence and its reverse are then compared. The code is accepted as a Bi-directional code if the sequence is "greater" than or "equal" to its reverse. If the code is less than its reverse it is not used. For the label shown in Fig 1 which has 10 elements and a maximum gap size of 18 there are 781495 unique Bi-directional codes that can be represented in this code space.

The reading apparatus measures a gap sequence which is compared with its reverse, if the reverse sequence is the "greater" of the two it is used instead of the measured sequence of gaps decoding. A typical enumeration method is to tabulate the valid Bi-directional gap sequences in order of magnitude for example by ensuring that the first sequence in the table is "greater" than the second sequence, the second sequence is "greater" than the third sequence and so on. The enumerated code is then the position of the matching gap sequence in the table.

According to another aspect of the present invention there is a Bi-directional coding scheme that allows the direction of reading of the label to be determined. The direction finding Bi-directional codes are found by taking each of the unique codes for example the code 3,2,2,1,7,0,0,2,1 above. The reverse of the gap sequence is formed to produce 1,2,0,0,7,1,2,2,3 in this case. The code and its reverse are then compared. The code is accepted as a Bi-directional enabling direction finding if the code is "greater" than its reverse. If the code is not "greater" than or "equal" to its reverse it is not a valid unique code. For the label shown in Fig 1, which has 10 elements and a maximum gap size of 18, there are 780080 unique Bi-directional direction finding codes that can be represented in this code space.

When such a code is read, the direction of reading can be found by comparing the sequence of gaps read and its reverse. If the sequence of gaps read is "greater" than its reverse then the direction of reading is interpreted as the forward direction. If not then the label is diagnosed as having been read in the reverse direction.

With such a code, the reading apparatus measures a gap sequence which is compared with its reverse, if the reverse sequence is the "greater" of the two it is used instead of the measured sequence of gaps in decoding. A typical enumeration method is to tabulate the valid Bi-directional direction finding gap sequences in order of magnitude for example by ensuring that the first sequence in the table is "greater" than the second sequence, the second sequence is "greater" than the third sequence and so on. The single entry in this table for each unique code is the "greater" of the gap sequence and its reversed form. The enumerated code is then the position of the matching gap sequence in the table.

According to another aspect of the present invention the direction information is used to interpreting additional information encoded in the individual element ~~properties. For example, for a label such as that shown in Fig 2, it allows individual elements of the label to be unambiguously identified if the label is coded with a Bi-~~ directional direction finding coding scheme, enabling the information encoded to be correctly read.

According to another aspect of the present invention, a long label is encoded with a repeating pattern of gaps. By slicing an adequate length of the label, the unique sequence can be identified and the label decoded. For example Fig 3 shows 4 cycles of a repeated code.

Fig 3 Repeated Code

The gap sequence for the code shown in Fig 3 is 3,1,0,1,3,1,0,1,3,1,0,1,3,1,0,1 and is four repetitions of the basic sequence of 3,1,0,1. This basic code has 4 gaps and a maximum gap of 5, which are the parameters of this example. It must be understood that the number of gaps G and the maximum gap size M are parameters of the code and may be any integer value that the reading apparatus is capable of decoding.

Provided a slice of the repeated code is taken so that at least G consecutive gaps can be measured, then the information coded into the label can be read. This will require at least G+1 complete elements to be read. The reader must account for situations where the slicing process cuts through material elements. These partial elements may give distorted signals, which the reading apparatus must ignore completely, or interpret as the signal from partial element, and interpret appropriately.

Each sequence of integers g1,g2,g3...,gG whose sum is the maximum gap size therefore represents a unique code in the code space which is characterised by the number of gaps G, and the maximum gap size M. For instance for the label shown in Fig 3 with a fixed code repeat distance, there are a total of 56 possible codes, only some of which are unique and suitable for use in a cyclical code. For instance a slice from label coded with the repeating gap sequence 3,1,0,1 could contain the gap sequence 1,0,1,3 since there is no control over where the slice of the label is taken from. Consequently these sequences correspond to the same code. The number of valid unique codes for this example is 14.

When decoding the gap sequence, the observed gap sequence of length G detected by the reading apparatus is "normalised", by circular rotation such that the first gap written is the largest gap. If there are two gaps which are the same, largest size, then the adjacent gaps are compared etc. For example the code 1,0,1,3 when normalised is 3,1,0,1 and the code 2,0,1,2 when normalised is 2,2,0,1. The normalised gap sequence is then enumerated to provide an output code number. A typical enumeration method is to tabulate the valid normalised gap sequences in order of magnitude for example by ensuring that the first sequence in the table is "greater" than the second sequence, the second sequence is "greater" than the third sequence

and so on. The enumerated code is then the position of the matching gap sequence in the table.

~~According to another aspect of the present invention, a long label is encoded with a~~ repeating pattern of gaps using a Bi-directional coding scheme. By slicing an adequate length of the label, the information encoded can be decoded irrespective of the direction of reading of the slice of label or from where in the label the slice was taken. Each sequence of integers g1,g2,g3...,gG whose sum is the maximum gap size therefore represents a unique code in the code space which is characterised by the number of gaps G, and the maximum gap size M. For instance for the label shown in Fig 3 which has 4 gaps and a maximum gap size of 5, with a fixed code repeat distance, there are a total of 56 possible codes, only some of which are unique and suitable for use in a reversible cyclical code. For instance a slice from label coded with the repeating gap sequence 3,1,0,1 could contain the gap sequence 1,0,1,3 since there is no control over where the slice of the label is taken from. Consequently these sequences correspond to the same code. Similarly the sequence 2,2,0,1 could be confused with the sequence 2,2,1,0 read in the reverse direction, these sequences correspond to the same Bi-directional code. For example, the number of unique Bi-directional codes for a 4 gap, maximum gap size 5, with a fixed code repeat distance is 10.

In order to decode such a label, the "normalised" reversed and "normalised" unreversed gap sequences of length G that was read are compared and the "larger" of the two is the gap sequence used for decoding. A typical enumeration method is to tabulate the unique normalised reversible gap sequences in order of magnitude for example by ensuring that the first sequence in the table is "greater" than the second sequence, the second sequence is "greater" than the third sequence and so on. The single entry in this table for each unique code is the "greater" of the "normalised" and "normalised" reversed forms. The enumerated code is then the position of the matching gap sequence in the table.

One embodiment of this aspect is a continuous thread-like label, a portion of which is cut and used to label an object. Provided that adequate length is cut to allow the label to be decoded, it does not matter from where the length of label is cut.

According to another aspect of the present invention, a long label is encoded using a pattern of gaps with a very long repeat distance. The pattern is generated from a binary sequence generator such as a decodable de Bruijn Sequence generator, or a pseudo random generator formed typically from a shift register of N bits with feedback from the contents of two taps exclusively "OR"-ed together. The sequence generator is chosen to provide a maximum length sequence. The gaps would encode the binary elements of the sequence. When coded in this way a slice of sufficient length of the label can be decoded to give a unique position in the sequence. This unique position can be interpreted as a label code.

According to another aspect of the present invention, a long label is encoded using a non-repeating pattern of elements whose properties, such as height and width are used to encode information. These elements are placed in a predictable grid of

positions. The pattern is generated from a sequence generator such as a pseudo-random binary sequence generator or other sequence generator such as A de Bruijn sequence. ~~The coded elements encode the binary elements of the sequence. When coded in this way a slice of sufficient length of the label can be decoded to give a~~ unique position in the sequence. This unique position can be interpreted as a label code. The grid of positions is used to decode the direction of scanning of the label and hence to decode the unique position of the label in the sequence to provide a unique identifier irrespective of the read direction.

Reference elements may be included at predictable intervals interspersed among the data carrying elements to simplify the decoding of the data carrying elements. These elements can also provide information to allow the direction of reading to be determined.

The positioning of the reference elements relative to the data carrying elements provides extra encoded information, separate from the data code sequence. This extra information can be used as a checksum to check correct decoding, alternatively the extra information can be used to identify the label code as coming from one of a number of codes sequences.

An example is shown in Fig 4. The code consists of blocks of 8 data elements, separated by reference elements (labelled R). The reference elements are of a known size and shape. The reference elements are identified by a unique sequence of gaps around them. For example in the code shown every second reference element has a large gap either side and so can be recognised. The intermediate reference elements have a large gap on one side only. In this way the references can be identified and the direction of reading can be determined. In this example there are 4 types of data element and the by identifying which of the 4 types is decoded 2 bits of binary information can be found 00,01,10 or 11 in binary. The number of types of data element may be 2 or more. By concatenating the data from 16 sequential data elements, taking the direction of reading into account, and ignoring the interspersed reference elements, a 32 bit sequence results. This 32 bit sequence is unique and identifies the position in the non repeating sequence from which the 16 data elements in the label was taken.

If the element spacing is nominally 1.5 mm, this sequence does not repeat for over 3800 kilometres, assuming that the reference marker spacing are 2mm. A slice of 30mm of this label from anywhere is sufficient to locate position to the nearest element position, approximately 1.5mm in the example shown. Over 100 million unique 30mm labels are be made by subdividing this long sequence. It must be understood that the parameters are examples, the number of element types, the number of elements, the reference marking gaps and the element pitches are all parameters that can be varied in such a scheme.

In this example, the position of the reference marker s is used to identifiy the code as coming from one of a set of eight code sequences, each of full length.

Fig 4: long non-repeating code

One embodiment of these long codes with non-repeating patterns is a code using magnetically active elements attached to a narrow flexible substrate in the form of a continuous thread. This thread is woven into a garment label of sufficient length so that the label sequence position can be determined. The thread does not have to be aligned in any special way with the garment label into which it is woven.

The unique position in the sequence decoded by reading the label is a unique identifier for the garment. By using a sequence, such as a decodable de Bruijn Sequence, the unique identifier may be decoded into a unique serial number for the label.

Typical applications of the continuous repeated and non-repeated codes are where labelling of objects is required in situations where the manufacturing methods employed to manufacture the objects use processing of continuous material. If labelling of a particular type, family or class of object is required, codes from the repeated code family described are used so that the type, family or class of object can be represented by the code used to label the object. If the objects need to be uniquely coded, a code from the non-repeating code family is appropriate.

One embodiment of these long non-repeating codes is a code using magnetically active elements attached to a narrow flexible substrate in the form of a continuous thread. This may used to label any security document, object, or token such as a bank note, by attaching or embedding a portion of thread. The properties of the non-repeating sequence will ensure that the document has a unique identity determined by the particular portion of sequence that forms part of the document. Using a decodable sequence, the decoded identities of the objects so labelled can arranged to be a monotonically increasing or monotonically decreasing integer numeric sequence.

Another embodiment of these long codes with non-repeating patterns is in position sensing where a track is formed from a sequence of coded magnetic elements. The location of the reading antenna can be determined by reading a short portion of the sequence and finding its position in the track to the nearest element position

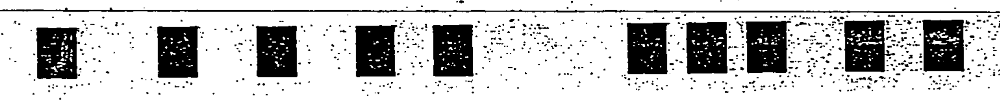

Fig 1: Linear label

Fig2: Linear label with coded element properties

Fig 3 Repeated Code

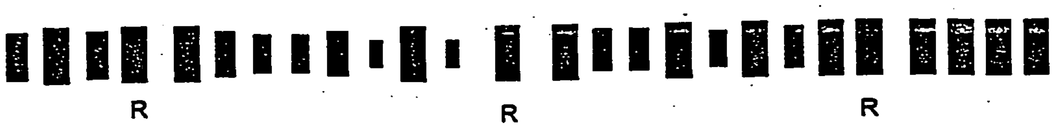

Fig 4: long non-repeating code

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16 Aug 00

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